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SPECIAL REPORT P2

STUDIES OF THE BIOLOGY AND CONTROL OF THE SPRUCE BUDWORM IN OREGON AND WASHINGTON

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TABLE OF CONTENTS

PAGE

SUMMARY

Studies of the spruce budworm and its natural enemies in Oregon and Washington were initiated cooperatively in 1950 by the New Haven, Connecticut, and Portland, Oregon, Forest Insect Laboratories. The purpose of the studies was to determine over a period of years the status of the budworm and its natural enemies on both sprayed and unsprayed areas. The work accomplished and findings during 1951 are recorded in the present report.

Three permanent study locations were selected in unsprayed areas in eastern Oregon to investigate the population trends of the budworm and its parasites. Collections of various life stages were made at five intervals during the season to determine the aggregate effect of parasitism in 1951 and the probable relative abundance of the budworm in 1952.

Twenty permanent study lines were also established, at random, in eight major spray units that were treated in 1949 or 1950. These lines were installed to study the long-term effects of spraying on both the budworm and its natural enemies, principally parasites. Collections of early-instar and mature larvae were made for population estimates and to determine the incidence of parasites and disease.

Other work accomplished during the season included: (1) Spot collections of immature and mature larvae on 14 unsprayed areas to learn the abundance of the budworm and natural control factors in these areas, (2) observations on the life history and ecology of the budworm, and (3) collection and shipment of a supply of the larvaevorid parasite *Ceromasia auricaudata* T.T. to the New Haven Forest Insect Laboratory for propagation and subsequent release in the Northeast.

A summary of the principal findings in 1951 is given below:

Results of Studies in Unsprayed Areas

1. No reduction of the budworm population was expected in 1952 on any of the three intensive study areas due to the natural control factors investigated.

2. Aggregate parasitism computed collectively for all stages of the budworm on the three study areas was 24.3 percent at Waterman Flat (Ochoco), 37.0 percent at North Powder (Whitman N.F.), and 38.6 percent at Cow Camp (Chesnimnus). Parasitism at this range is well below the level at which reduction can be expected with generally high budworm populations.

3. Preliminary evaluation of the budworm population on 14 other unsprayed areas was made; no indication of a lessening of the epidemic on these areas in 1952 was found.

Results of Studies in Sprayed Areas

1. The residual budworm population was found to be very light on 18 of the 20 study lines established; considerable buildup had occurred on the two remaining lines (in the Mt. Hood area sprayed in 1949) where spray was applied too late to be fully effective.

2. The budworm population on study lines west of the Cascades Mountains was especially low.

3. Parasites of early-instar larvae obviously survived the spraying very well and were exerting considerable pressure on the residual budworm population.

4. Most of the common species of parasites of mature larvae were also recovered, although it appeared that they were reduced to a relatively low level by spraying.

5. Due to the very small numbers of budworm larvae remaining on the bulk of the sprayed areas a comprehensive evaluation of the status of budworm parasites from area to area was not possible in 1951.

INTRODUCTION

The spruce budworm (*Choristoneura fumiferana* (Clem.)) has been widely epidemic in the Douglas fir and balsam fir stands of Oregon and Washington since 1944. Based on experimental spraying in 1948, control projects were carried out in 1949 (267,000 acres), 1950 (933,000 acres), and 1951 (927,000 acres). Highly satisfactory control of the budworm has been achieved on the sprayed areas.

Direct control has been applied only in those areas where tree-killing was in progress or was imminent, with the realization that it is a means of holding the budworm in check only until natural control factors are able to suppress the outbreak. Accordingly it is highly important that the status of these factors be followed closely to allow prompt cessation of costly control activities when the anticipated break in the epidemic occurs. It is also important that the residual budworm population on areas already treated be studied to determine if any buildup has occurred. It was to investigate these and associated problems that studies were initiated in 1950 and continued in 1951.

Results of the 1950 work (2) 1/ which included observations on some of the habits of the budworm in addition to studies of natural control were briefly as follows: (1) Adequate natural control was not expected in 1951 on the three areas studied; (2) development of budworm larvae on trees with abundant staminate cones is at first accelerated, but by the time larvae are mature no effect is apparent; (3) hibernating populations on the trunk and limbs provide a reasonable index to subsequent feeding populations; and (4) the proportion of the budworm population found on the foliated twigs changes considerably throughout the life history of the insect, with the result that the commonly-used 15-inch branch sample may be inadequate for sampling some stages, such as eggs.

1/ Numbers in parentheses refer to reports and publications listed under Literature Cited, page 21.

The following report describes the conduct and results of the 1951 studies as outlined in the annual project work plan, dated April 26, 1951 (5). Acknowledgment for invaluable assistance on these studies is made to Mr. K. Baxter, student assistant employed by the New Haven Laboratory who took part in all phases of the work; and to R. Fredsall and C. Rauch, student assistants of the Portland Laboratory, and B. Hayes and A. Lindsten, foresters of the Oregon State Board of Forestry, all of whom assisted in making collections at various times during the season. Sincere appreciation is expressed to the Staff of the Union Ranger District, U. S. Forest Service, Union, Oregon who provided space and facilities for the field laboratory.

OBJECTIVES

The basic objectives of the investigations were to determine (1) the biology and natural control of the budworm on unsprayed areas and (2) the status of the budworm and its natural enemies on sprayed areas. As guides for reaching these objectives, the following questions were set up as being goals for which answers were needed.

Biological Studies in Unsprayed Areas.

(1) What effect are natural control factors, mainly parasites, predators and disease, exerting on the present budworm population?

(2) What is the status of natural control factors on the remaining untreated areas in Oregon and Washington?

(3) What ecological factors are affecting the abundance of the budworm in the present infestation?

(4) What are the detailed life cycle and habits of the budworm in the Northwest?

Biological Studies in Sprayed Areas.

(1) To what extent has infiltration and reinfestation occurred in treated areas?

(2) What effect has spraying had on natural control factors, principally parasites of the budworm?

A supplemental phase of the work was to attempt to obtain a supply of the parasite Ceromasia auricaudata T. T. for shipment to the New Haven Laboratory for propagation and eventual distribution in the Northeast.

BIOLOGICAL STUDIES IN UNSPRAYED AREAS

Status of the Budworm and its Natural Control Factors, Mainly Parasites, Predators, and Disease in Study Areas

For these studies it was desired to confine investigations to areas that would not be treated in 1951 and were unlikely to be treated for several years. This would allow investigations to be continued in the same areas for a considerable time, permitting the trends of natural control factors to be followed. Unfortunately this has not been entirely possible due to the continuing large-scale control program. Two of the areas studied intensively in 1950, La Grande and Minam, were treated in 1951.

Following is a description of the areas studied, the methods used and the findings:

Areas Studied - Of the three study areas used in 1950, only the Chesnimnus area remained untreated in 1951. However, new studies were initiated in two widely separated and distinctive infestations:

(1) The Waterman Flat locality in the Ochoco area of north central Oregon, and (2) the North Powder River area in the Whitman National Forest in eastern Oregon. Both are relatively new infestations. Along the North Powder River, the infestation is light and an excellent opportunity exists to continue studies for several years.

Sampling Procedure and Study Methods - Studies of an intensive nature were conducted, based on the following methods.

(1) In the Waterman Flat and North Powder River localities, ten permanent collecting points were established at 5-chain intervals on a compass line. The number of existing points at Chesnimnus was increased from five to ten, with a 3.5-chain interval.

(2) Collections were made of needle-mining larvae (except at Chesnimnus), larvae feeding in the expanding buds, mature (sixth instar) larvae, pupae, and egg masses.

(3) Collections of larvae in the needles and in buds were made from foliage samples of uniform size in each study area. At Waterman Flat, five 15-inch twigs were taken from each of two trees per collecting point, using a 30-foot pole-pruner, while at North Powder River five twigs were taken from each of three trees per point. At Chesnimnus the bud-mining population was sampled at one selected tree per station, by removing half a branch whorl (normally two branches) at midcrown. For examination the branch was divided into 15-inch twigs and remainder of foliage. The larvae obtained from all collections were saved for subsequent dissection for parasites. All paralyzed or moribund larvae from the bud collection were held and examined for external parasites.

(4) Collections of mature larvae and pupae were made on the basis of a predetermined number of specimens per collecting point. At each point 25 mature larvae were placed in alcohol for future dissection, while a smaller number from each point (usually 20 but varying with ease of collection) were saved for rearing in cloth-bottom trays. Between 20 and 30 pupae per collecting point were saved for individual rearing in gelatin capsules.

(5) The egg mass collecting consisted of taking two branches at midcrown from one tree at each collecting point and examining these branches for egg masses. For examination these branches were divided into 15-inch twigs and remainder of branch. This whole branch sample is necessary because a large proportion of the eggs are deposited on foliage toward the center of the crown.

(6) For each study area, the mortality caused by the various natural control factors was calculated for each life stage collected. The various percentages of mortality were then used to calculate an aggregate mortality figure for the area.

Results of Studies - The above sampling procedure was designed to provide estimates of existing budworm populations, as well as to obtain host material for parasite studies. Population counts alone may show the trend of the infestation, while studies of natural control factors may reveal why population changes occur. Following are results of the studies and discussion of their significance.

1. Budworm population estimates. Counts on a 15-inch twig basis are used to compare populations between study areas and from year to year. This unit of sample is especially useful when the larvae are feeding in the buds, as a large majority of them are near the periphery of the crown at this time. Sampling for other stages on a 15-inch twig basis, to follow seasonal changes in population, are also of value if their limitations are understood. For instance, the 15-inch twig sample for the needle-mining stage is not entirely reliable since only part of the larvae are on the twigs at this time, and furthermore, some larvae may still not have broken hibernation. To estimate next year's brood, an egg-mass count is necessary. Since the majority of the masses are deposited on foliage nearer the center of the crown, the 15-inch twig is least useful for sampling this stage. Hence whole branches are used as a sampling unit. However, it is believed that with normal winter mortality taken into account, the hatched eggs on the 15-inch twigs may be a fair approximation of the following spring's population in the buds.

With these facts in mind, a comparison of the population in the buds (1951 brood) with the new population in the egg stage (1952 brood) indicated an increase in budworm population in all three study areas in 1952. These data are presented in Table 1.

2. Estimates of Natural Control. Aggregrate parasitism ranging from 24.3 to 38.6 percent, was generally light at all three intensive study plots and no immediate reduction of the budworm population was indicated. Table 2 summarizes the effect of parasites as natural control factors in these areas.

Parasites of small larvae exerted a moderate effect, accounting for a 19 to 26 percent decrease of the budworm population. Two parasites, Apanteles fumiferanae Vier. and Glypta fumiferanae (Vier.), were responsible for nearly all of this parasitism, although Campoplex sp. was also recovered at all three areas. Mortality of budworm during the bud-mining period, in the form of moribund or paralyzed larvae, was very light and no external parasites were found.

Parasitism of mature larvae, from both rearing and dissection was unexpectedly light (Table 3). However, the material preserved in alcohol and later dissected showed a higher proportion of parasites than did the rearing, apparently due to the frailty of Phytodietus (and possibly Omotoma) in transportation or rearing. The hymenopteron Phytodietus fumiferanae Rohw. was present in all three areas, while the larvaevorid Omotoma fumiferanae (Toth.)was more common at both North Powder River and Chesnimnus. Ceromasia auricaudata T.T. was recovered in small numbers at North Powder River and Waterman Flat, while Madremyia saundersii Will. was found only at Waterman Flat. Some difficulty in timing these collections was encountered at Waterman Flat and Chesnimnus due to inconsistent variation in development. However, only at Chesnimnus did emergence from the pupal collection show a proportion of larval parasites definitely higher than that obtained from the larval collection. (Since the maggots of Omotoma, Ceromasia, and Madremyia do not issue until several days after the host pupates, the pupal collection often has value as a check on the accuracy of the mature larva parasitism.)

Parasites of pupae were also scarce (Table 2). The hymenopterous pupal parasites Phaeogenes hariolus Cress., Ephialtes ontario Cress., and Itoplectis obesus Cush.,along with the sarcophagid Agria affinis(Fall.) were recovered at Chesnimnus, but only I. obesus was found at the other study areas.

Egg parasitism was exceedingly light both in 1950 and 1951. In 1951 the egg parasite Trichogramma minutum Riley was not found in egg mass collections at North Powder River and Waterman Flat, while at Chesnimnus it exerted a parasitism of only 2 percent. In 1950 egg parasitism at Chesnimnus was about 3 percent. Examination of 1950 egg masses at Waterman Flat, collected incidentally with mined needles in the spring of 1951, showed only one egg to be parasitized.

While parasitism was impressive at none of the three areas, at North Powder there was a reasonably high parasitism of mature larvae for such a light and relatively new infestation. In the Ochoco area the budworm population seemed to be well ahead of natural control factors while at Chesnimnus it was at a high level, yet appeared to be static despite the low parasitism.

At Chesnimnus, no reliable prediction of budworm population trend seemed possible by the end of 1951. In 1950 a high mortality of pupae occurred here, apparently from disease. In June 1951, a collection of 300 larvae from Chesnimnus was sent to the Laboratory of Insect Pathology at Sault Ste. Marie, Canada to be reared for disease. J. MacBain Cameron, officer in charge, reported that 56 of the 131 specimens that died showed evidence of being infected with capsule disease, but that such incidence could be expected. At any rate, considering the low parasitism in this area, there apparently are physiological or ecological factors akin to disease which are operative and holding the budworm population at a static, although high level.

Status of the Budworm and its Control Factors on other Untreated Areas.

Collections of early instar and mature larvae were made at 14 widely-scattered locations in the remaining untreated areas of northeast Oregon. Approximately 50 larvae were collected at each of the sampling points for eventual dissection to determine the abundance of the major parasites in these unsprayed areas. Unfortunately most of these larvae have not been dissected to date. The remaining larvae, which are preserved in alcohol, will be dissected as time permits, and the incidence of parasitism recorded for comparison with future dissections from the same points. These records will be especially valuable for correlation with any major fluctuation in the budworm population that may occur in these areas.

Although the incidence of parasitism in these areas has not yet been fully evaluated, there was no visible indication of population reduction when the last field examination was made as the larvae were approaching pupation. There was little doubt that the 1952 budworm population in these areas would continue to be high.

Ecological Factors Affecting the Abundance of the Spruce Budworm

Due to time and personnel limitations, no formal investigations of the ecology of the budworm were planned, although the need for them was recognized. Miscellaneous observations were made during the course of other work on (1) relative susceptibility of host species and (2) degree of damage in stands varying in age, vigor, and composition.

Variation in susceptibility between the two most abundant and commonly attacked species, Douglas fir (*Pseudotsuga taxifolia* Britt)and the white firs (*Abies grandis* Lind. and *Abies concolor* L. & G.), seems apparent in some stands. In the aggregate, however, no clear-cut preference for either host species by the budworm could be established. In the dry-site stands of eastern Oregon and Washington the impression was gained that comparable populations of the budworm caused more severe defoliation to Douglas fir than the white firs. The basic reason for this seems to be that even slight feeding or mining of the short Douglas fir needles results in their death, whereas, the much larger white fir needles continue to function even after severe damage. In the wet-site western Oregon stands where Douglas fir needles are much nearer the same size as those of the white firs, no variation in damage was apparent.

In comparison with the above two host species, it appears that alpine fir (*Abies lasiocarpa* Nutt.) suffers considerably less damage, despite supporting very heavy populations at times. The reason for this situation is not known although the extremely dense foliage and relatively short seasons at the high elevations where this species grows may be at least partly responsible. The effects of a two-year life cycle of the budworm, which has been detected but not evaluated, in these areas may also be accountable.

The infested alpine fir is a difficult problem in the control program that is being carried on against the present budworm outbreak. It is often desirable to treat these stands, largely to prevent them from being a source of reinfestation to sprayed areas. However, since most of the alpine fir is at high elevation it is of little value other than watershed cover, and often is physically very difficult to spray due to the high elevation and rough topography.

Engelmann spruce (Picea engelmanni Engelm.), ponderosa pine (Pinus ponderosa Laws. and western larch (Larix occidentalis Nutt.), are attacked by the spruce budworm where these species are intermingled with infested fir. Noticeable although seldom serious damage may occur to the spruce; feeding on the pine and larch is usually little more than incidental. However, a pine form of the budworm tentatively identified as Archips retiniana has caused significant defoliation and some killing of leaders and branch terminals in a few localities.

To date there is no tangible evidence that the age of Douglas fir or white fir can be positively correlated with incidence of attack by the budworm. There is on the other hand, little doubt that reproduction, poles, and young-mature stands suffer much more serious damage than does mature timber. This is accountable for in that the percentage of new growth, the favored food of the budworm, is much higher on young, fast-growing trees, with the result that defoliation is correspondingly much more severe. Serious tree mortality and top killing have occurred in many young stands, but permanent damage in mature timber has been confined to a few areas.

Insufficient observation has been made so far to draw even tentative conclusions on the effect of stand vigor, site, and composition on incidence of damage by the budworm. So far the outbreaks in the high-volume stands of western Oregon have been mostly on relatively poor sites, with the trees on south and west exposure appearing to be the most seriously defoliated. Similar observations have not yet been made in eastern Oregon and Washington stands to attempt to correlate incidence of attack with forest growing conditions.

Investigations of the Life Cycle and Habits of the Budworm

As with the ecological problems no formal studies on the life cycle and habits of the insect were made in 1951. However, in the course of the detailed work on rearing, scheduling collections, and population sampling a variety of associated data on the habits of the budworm were secured. These data for 1951 will not be discussed here since they are treated throughout the report. However, in order that the nature of all budworm biological investigations made in Oregon and Washington since their inception in 1948 be brought together, the work done during 1948-50 is briefly described in the following paragraphs.

Knowledge of the life cycle and detailed habits of the budworm in this region was very limited prior to 1948 when Speers (3) made intensive biological studies in connection with an experiment in eastern Oregon to develop aerial spraying techniques. At this time comprehensive investigations were made of hibernating and feeding habits of the western budworm, and, of special significance, the rate of budworm development as correlated with development of new foliage of the host. Some work was also done at this time on natural control factors present in the study area.

Biological work in 1949 was carried out near Union, Oregon, by W. D. Buchanan (1) and was aimed primarily at obtaining a supply of the larvaevorid parasite Ceromasia auricaudata T.T. and the ichneumonid Phytodietus fumiferanae Rohw. for liberation in the state of Maine. Mass rearings of the budworm host produced several hundred of the desired parasites, but fell considerably short of the desired number. A limited amount of biological work was also done in 1949 by Wright (4) in connection with the control program of that year.

Studies by V. M. Carolin in 1950 were directed toward investigation of natural control factors of the budworm, particularly parasites, but also included work on (1) the feasibility of using hibernating populations as a measure of subsequent feeding populations, (2) procedures for sampling populations during different stages, and (3) budworm larval development under various conditions. The work done in 1950 was much more intensive than any done previously,with the results providing a working knowledge of the habits of the budworm in the Northwest. One of the significant findings of this season was that the budworm has a two-year life cycle at high elevations in the region.

As the result of the studies since 1948 the general habits of the budworm in Oregon and Washington are reasonably well known. Much is still to be learned about the budworm, however, in respect to methods of sampling populations dispersal habits of larvae and adults, the role of various natural control factors, the significance of the two-year life cycle, and a number of other related problems.

BIOLOGICAL STUDIES IN SPRAYED AREAS

Status of the Budworm Population

The immediate objective of these studies was to determine the status of the budworm and its parasites on previously sprayed areas. It is extremely important from the control standpoint to learn whether the residual populations from spraying will remain at a low level or commence to build up again to epidemic proportions, and, if buildup does recur, how long a period of protection is obtained by the direct control. Detailed pre-spray records are available for a great many treated areas to compare the populations existing prior to, and immediately after, spray application with the present population. It may be possible through study to determine at what stage of an epidemic direct control may be applied to obtain the most lasting effect.

Areas Studied. The following treated units were selected for study: (See map in Appendix).

Western Oregon	
(1) Eugene	sprayed in 1949
(2) Mt. Hood	sprayed in 1949
(3) McKenzie	sprayed in 1950
(4) Roseburg	sprayed in 1950
Eastern Oregon	
(5) Catherine Creek	sprayed in 1950
(6) South Umatilla	sprayed in 1950
(7) Tollgate	sprayed in 1950
Southeastern Washington	
(8) Walla Walla	sprayed in 1950

Sampling Locations. A varying number of permanent study lines, from one to five, were established in each of the above areas. An attempt was made to place these lines in the same location as mortality lines used in evaluating the spraying. On all but one of the total of 20 lines, ten permanent sample points at approximately 5-chain intervals were established and marked by blazing the nearest tree to the plot center. On one line only five sample points were established. The location of the starting points and compass courses of the lines were recorded on plot forms. These lines were established when the initial examination for population evaluation was made.

Because of the priority assigned to higher value timber, 12 study lines were established in four sprayed areas in western Oregon, while only 8 study lines were established in four areas in eastern Oregon and Washington.

Sampling Procedure and Study Methods - The population sampling was confined to two stages of the budworm --larvae in the buds and mature larvae. The procedure employed was as follows:

(1) Collections of Larvae in the Buds. To obtain counts of the population in the buds, 2 to 4 branches were cut from each of the three trees nearest each of the ten collecting stations. Branches were taken from as many crown levels as possible, so as to make the sample representative. Ten 15-inch twigs were removed at random from the branches cut from each tree, making a sample of 300 twigs for the line; the buds on these twigs were then examined for budworm larvae. All larvae found were placed in vials of alcohol for subsequent dissection.

Original plans were to sample the spring population by collections of larvae in hibernation and in the needles. It is fortunate that time did not permit this approach, since sampling the population in the buds proved to be the simplest and least time consuming.

(2) Collections of Mature Larvae and Early Pupae. Counts and collections were made when the bulk of the larvae were in the sixth instar, with the remainder 5th instar and pupae. Some collections were made too early to secure optimum representation of parasites of mature larvae, as was evidenced by the number of stunted larvae (containing parasites that attack overwintering budworms) that were found. This was true for the three lines in the South Umatilla area and the Bald Mt. Road line in the Catherine Creek area. Because populations in general were at a low level, the basis for sampling was 30 minutes beating time by two men at each collecting station. All larvae obtained were preserved in alcohol for later dissection.

Population Estimates - The residual budworm population in these sprayed areas, on the basis of the above collections, was found to be generally very light, as is shown in Tables 4 and 5. Exceptions were two localities in the Mt. Hood area, sprayed in 1949, where considerable infiltration and build-up had taken place, and one locality in the Catherine Creek area. Of these, the Beaver Butte Creek locality (Mt. Hood) showed approximately 2.6 larvae per 15-inch twig, while the Bear Springs (Mt. Hood) and Reeves Mt. (Catherine Creek) localities showed about 0.25 larvae per 15-inch twig. The larval population per 15-inch twig prior to spraying on these three areas was 14.6, 8.8, and 6.5, respectively. It is likely the Beaver Butte Creek locality may warrant direct control in the near future.

With the exception of two of the three Mt. Hood localities, which are on the east slope of the Cascade Mountains, residual populations in western Oregon were considerably lower than those in eastern Oregon. In the Eugene area (western Oregon) not one of the five study lines showed more than 3 budworm larvae on 300 15-inch twigs. It should be noted that where the area of infestation could be treated completely in one season (ie. the Eugene areas), the effect of control measures is more lasting.

On most of the study lines the numbers of mature larvae collected, although secured on a beating time basis, reflected the population counts obtained from larvae in the buds (Table 4). Normally, considerably higher numbers of mature larvae can be collected by beating, as compared with sampling a prescribed number of twigs. It is well to point out, however, that the comparison of counts of mature larvae obtained by beating from different lines has certain limitations. One of these is the varying number of small larvae, probably containing parasites, that are still found relatively late in the season, and another is the ability and industry of the collectors.

Status of Natural Control Factors, Principally Parasites

The larvae collected during the early and late stages described above were subsequently dissected to determine the prevalence of the major parasites. This was done because studies in the unsprayed areas in Oregon have shown that the two main groups of parasites responsible for most of the budworm mortality caused by these natural control agents can be recovered from these larval stages. They are (1) parasites attacking overwintering larvae (recovered from larvae in the buds), and (2) parasites of mature larvae.

It was hoped that where larvae were scarce additional specimens could be obtained by more intensive collecting so as to allow more significant determination of percent parasitism. This did not prove practicable, however, with the existing limitations of time and manpower. It was fortunate that where only a single study line was located in a major control unit or area, the data obtained were sufficient for analysis.

The parasites recovered from budworm populations on sprayed areas in eastern and western Oregon are shown in Table 6. A discussion of their significance follows.

Parasitism of small larvae - Dissections of larvae in the buds showed an excellent survival of Apanteles, Glypta, and Campoplex. These parasites apparently escaped the effect of the spray by being in the security of their cocoons or within the host. Totals by spray area, where 24 or more larvae were found during the bud examinations, show a parasitism ranging from 38 to 59 percent. In areas where smaller numbers of larvae were collected, the parasitism was still substantial, but the individual figures may not be reliable due to the meager data.

The parasite Campoplex sp., showing a parasitism of 4 to 23 percent, appears to be exerting a much greater effect at this low level of host density than previously with higher pre-spray populations. Studies by Speers in 1948 and Carolin in 1950 at various unsprayed study plots in eastern Oregon showed a parasitism of only 1 to 6 percent. In 1951 Apanteles was still the most important parasite of overwintering larvae, however, with Campoplex second and Glypta third.

Parasitism of mature larvae - One of the problems of obtaining an accurate picture of parasitism for this stage is the proper timing of collections, since most of these parasites attack the budworm only a few days before pupation. Since the collections points were well scattered over Oregon and part of southwest Washington, timing was very difficult; a few collections may have given a minimum figure of parasitism of mature larvae.

It was anticipated that parasites of mature larvae, particularly larvaevorid flies, would not survive the spraying to the same extent as parasites of small larvae. In several cases this appeared to be true, and generally only one or two of the several species commonly found in unsprayed areas were recovered from the sprayed localities studied. Whether this indicates differential survival between species can be determined only by consulting pre-spray records. For purposes of discussion the Beaver Butte Creek (Mt. Hood) area which again harbors an epidemic infestation, is not included in the following general summary.

On some spray areas where a moderate survival of budworm had occurred, parasitism of mature larvae was high in 1951. Three species in particular demonstrated ability to survive the control treatment. Lypha setifacies West was singularly effective at Creswell, Frissell Crossing, and Bear Springs, all in western Oregon. In eastern Oregon Actia interrupta Curr. was very effective at Langdon Lake where alpine fir is the host species for the budworm and was very common at Baby Springs and Reeves Mt.; it was also recovered from three other localities. Phytodietus fumiferanae Rohw., a hymenopteron, was highly effective at Henry Mill and was recovered from five other localities. The external egg of Omotoma fumiferanae (Toth)was found on larvae from all three Catherine Creek lines.

Noticeably lacking from all localities was the larvaevorid parasite Ceromasia auricaudata T.T., at times an important budworm parasite in the West. At four of the Eugene localities and two of those at Roseburg, where collections were well-timed, no parasites of mature larvae were found. However, host specimens were few in number, and further collecting would doubtless have disclosed larvae with parasites.

BIOLOGICAL STUDIES ON THE PARASITE
Ceromasia auricaudata T.T.

It was desired that approximately 50 puparia of *Ceromasia* be obtained for propagation of this parasite at the New Haven Laboratory. The work in 1950 had shown this species to be much less common in Oregon than earlier reports indicated. In addition most of the infestations in the vicinity of the Union field laboratory had been treated or were being treated. It was therefore necessary to depend upon the following variety of collections, some of a preliminary nature, to increase the chances of finding sufficient *Ceromasia*.

(1) Beaver Butte Creek (Mt. Hood). Following the mature larvae collection as part of the post-control studies, two survey men collected 1600 larvae for rearing at the Union laboratory. One *Ceromasia* puparium was recovered.

(2) Looking Glass area, north of Elgin. Spot collections of mature larvae and pupae were made at the lower altitudes. If these had been productive, larger collections would have been made at higher altitudes where parasites had not yet emerged. No *Ceromasia* puparia were recovered.

(3) Regular collections of mature larvae in the three intensive study areas. Five *Ceromasia* puparia were recovered.

(4) Bear Creek, near Wallowa. A collection of 620 newly formed pupae produced 73 *Ceromasia* puparia, representing a parasitism of about 12 percent. The overall parasitism by larval parasites in this area was 31 percent.

(5) Timothy Springs, on the Tollgate-Troy Road. A collection of 125 larvae and prepupae produced two *Ceromasia* puparia.

Although *Ceromasia* was recovered in quantity only at Bear Creek, sufficient puparia were obtained for propagation. However, after the laboratory stock had passed through one generation in an alternate host, the cabbage butterfly, only male flies resulted. Inasmuch as Canadian workers also encountered this same puzzling situation in 1951, it is evident that other techniques for propagating this parasite in the laboratory are needed.

One objective of these studies was to correlate Ceromasia, if found, with the incidence of other lepidopterous hosts, since laboratory rearing has shown a number of hosts to be satisfactory. Along Bear Creek there are sufficient hardwoods to maintain an alternate host, such as Archips cerasivorana Fitch. which is occasionally abundant on choke cherry. While a search in mid-July failed to disclose evidence of any such species, efforts earlier in the season might have been successful.

RECOMMENDATIONS FOR FURTHER STUDY

It is important that the present studies be continued for several years, since their principal value will be in the long-term trend data secured. The number of areas now being studied, both sprayed and unsprayed, is an absolute minimum if significant data are to be obtained. The work carried out in 1951 is the maximum that can be undertaken by one full time worker and a seasonal assistant. To increase the scope of the investigations, which is badly needed, would require a corresponding increase in personnel.

Since the chance of increasing the number of personnel assigned to this project seems remote at this time, it is recommended that for the present the work be carried along at the existing level. This includes (1) following population trends on the eight sprayed areas and (2) conducting intensive biological studies on three unsprayed areas. It is most important that the unsprayed areas now being studied be reserved from the control program. Continued investment in installation and maintenance of permanent plots is unwarranted unless assurance is received from control agencies that the areas will not be treated.

During the course of the work to date, a number of items concerning the biology and sampling of the budworm that obviously need investigation have become apparent. In most instances full-time studies for one season or more would be needed to adequately investigate them. In some cases, however, at least observational data can be secured while doing regularly scheduled work. Furthermore, it is well to make record of these problems needing investigation, in case the facilities for undertaking the needed research become available. Following is a list of problems, stated as questions, on which studies should be made when possible.

1. Where do budworm larvae pupate when the host tree is stripped of foliage? Also, where are the eggs laid under such circumstances?

2. What is the optimum time for making population estimates of larvae in the buds? Complicating factors are the lag of larvae leaving mined needles, particularly on white fir, and the effect of staminate cones when present.

3. In sampling large trees in western Oregon it is possible, even with a 30-foot pole pruner, to sample only the lower limbs. How much error is thereby introduced into the population estimate, and how much less is parasite activity on the shaded lower branches?

4. What are the details of the two-year life cycle that presumably is common at high elevations? In the 1950 work an occasional 4th instar larva was recovered from bark samples boxed to secure hibernating larvae. Does this indicate a mixing of the two-year and one-year cycle budworms?

5. Is wind a significant factor in the dispersal of small budworm larvae in this region, and if so, what threat does this impose toward reinfestation of sprayed areas. Also, what is the role of migrating adults in this respect?

6. When it is impossible to visit collecting areas regularly, due to distance and time factors, what method can be employed to collect mature larvae for parasites? How much error is introduced by collecting before pupation of the host has begun?

7. In some areas such as that at Chesnimnus, natural control factors other than parasites have caused the epidemic to remain at a static, yet high level. What are the factors responsible?

8. What effect do stand age, vigor and composition have on susceptibility to attack by the budworm?

9. At what level of defoliation does significant reduction in radial increment occur?

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A P P E N D I X

PRIMARY PARASITES RECOVERED FROM THE SPRUCE BUDWORM IN OREGON, 1949-1951

	Stage Attacked	Stage of Emergence	Abundance
HYMENOPTERA			
Braconidae			
Apanteles fumiferanae Vier.	2d instar larvae	5th instar larvae	abundant
Meteorus species 1/	5th instar larvae	mature larvae	rare
Microbracon sp.	mature larvae	mature larvae	rare
Ichneumonidae			
Campoplex (= Horogenes) species	2d instar larvae	5th instar larvae	rare to common
Campoplegine, species unknown	?	mature larvae	rare
Ephialtes ontario (Cress.)	prepupae and pupae	pupae	rare
Glypta fumiferanae (Vier.)	2d instar larvae	5th instar larvae	common
Horogenes cacoeciae (Vier.)	2d instar larvae	mature larvae	rare
Itoplectis obesus (Cush.)	prepupae and pupae	pupae	common
Labrorhychus species	mature larvae	pupae	rare
Phaeogenes hariolus (Cress.)	prepupae and pupae	pupae	rare
Phytodietus fumiferanae Rohw.	mature larvae	mature larvae	common
Scambus alboricta (Cress.)	mature larvae	mature larvae	rare
Chalcidoidea			
Elachertus cacoeciae How.	mature larvae	mature larvae	rare
Trichogramma minutum Riley	eggs	eggs	rare
DIPTERA			
Larvaevoridae			
Actia interrupta Curran	mature larvae	mature larvae	rare, locally common
Aplomya caesar (Ald.)	mature larvae	mature larvae and pupae	rare
Ceromasia auricaudata T.T.	mature larvae	pupae	rare, locally common

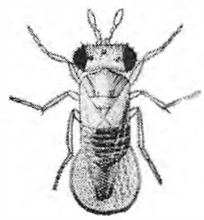
(Continued)

PRIMARY PARASITES RECOVERED FROM THE SPRUCE BUDWORM IN OREGON 1949-1951

	Stage Attacked	Stage of Emergence	Abundance
Lypha setifacies West	mature larvae	mature larvae	common in Cascades
Madremyia saundersii Will.	mature larvae	mature larvae and pupae	rare to common
Omotoma fumiferanae (Toth.)	mature larvae	pupae	common in eastern Oregon
Phorocera erecta Coq.	mature larvae	pupae	rare
Phorocera incrassata Smith	mature larvae	pupae	rare
Phryxe pecosensis T.T.	mature larvae	mature larvae and pupae	rare
Sarchophagidae			
Agria affinis (Fall.)	mature larvae and pupae	pupae	rare

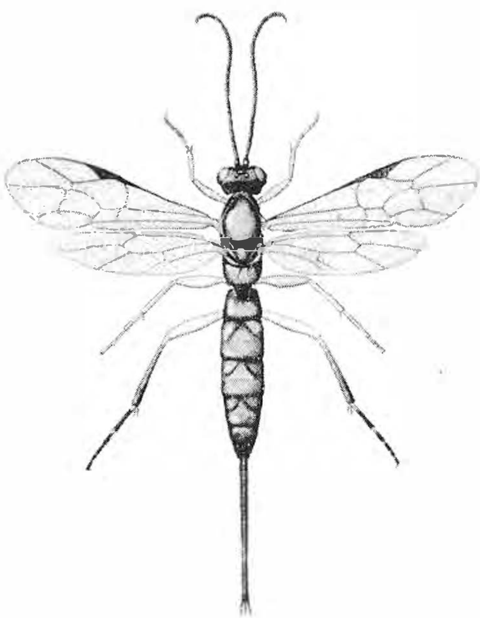
1/ Species found only by dissection of host material.

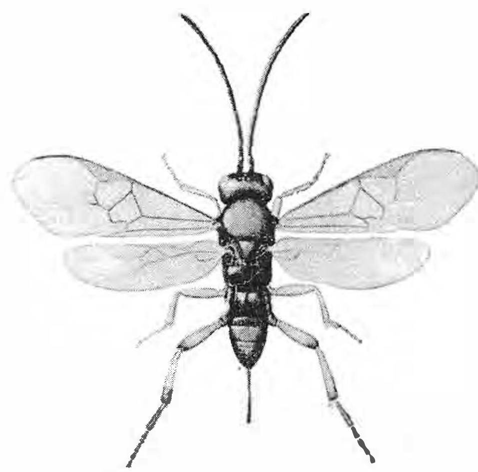
PLATE I



EGG PARASITE

Fig. 1. Trichogramma minutum Riley





PARASITES ATTACKING HIBERNATING LARVAE

Fig. 2. Glypta fumiferanae (Vier.)   Fig. 3. Apanteles fumiferanae Vier.

(Illustrations Greatly Enlarged)

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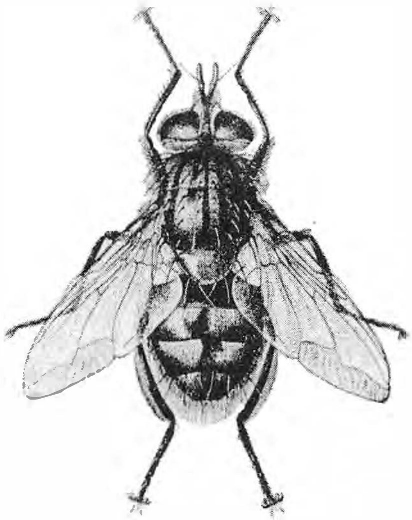
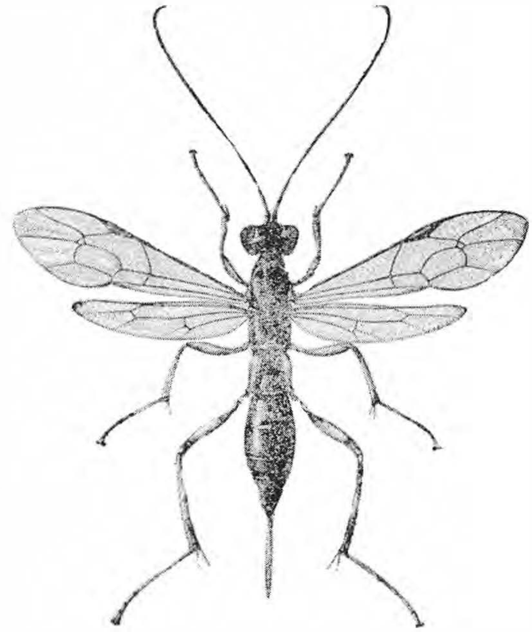
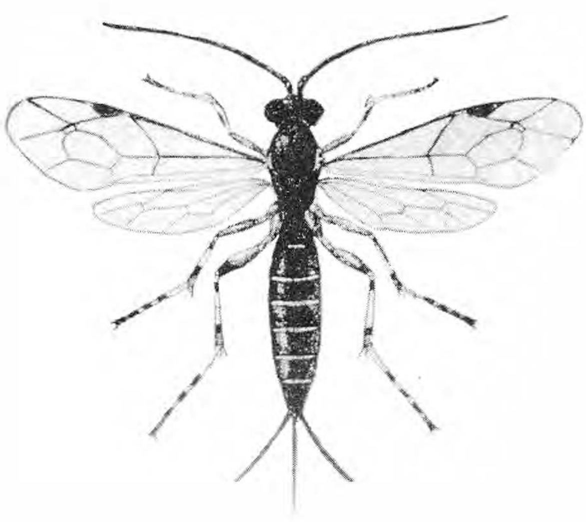
PLATE II





PARASITES ATTACKING MATURE LARVAE

Fig. 4. Omotoma fumiferanae (Toth.)   Fig. 5. Phytodietus fumiferanae Rohw.



PARASITE ATTACKING PUPAE

Fig. 6. Itoplectis obesus (Cush.)

(Illustrations Greatly Enlarged)

ADR-BCS-PORTLAND, ORE. FEB. 1953

TABLE 1. ESTIMATES OF SPRUCE BUDWORM POPULATIONS IN THREE UNSPRAYED STUDY AREAS IN EASTERN OREGON IN 1951

Study Locality	Larvae in Needles: No. 15" Twigs Sampled	Larvae in Needles: No. Budworm per 15-inch Twig	Larvae in Buds: No. 15" Twigs Sampled	Larvae in Buds: Budworm per 15-inch Twig	Egg Masses: No. Branches Sampled	Egg Masses: No. of 15-inch Twigs	No. of Egg Masses 1/: On 15-inch Twigs	No. of Egg Masses 1/: On Remainder of Foliage	Total
North Powder R.	150	0.5	150	0.7	20	167	4	14	18
Waterman Flat	100	1.7	100	3.7	20	157	22	42	64
Chesnimnus	--	--	--	3.4	20	172	29	52	81

1/ Approximately 45 eggs per egg mass.

TABLE 2. PERCENT PARASITISM OF THE SPRUCE BUDWORM ON THREE UNSPRAYED STUDY AREAS IN EASTERN OREGON IN 1951

Study Locality	Parasitism (In Percent) Of Life Stages: Eggs 1950 (by Trichogramma)	4th instar larvae (unknown causes)	5th instar larvae (by Apanteles, Glypta, Campoplex)	Mature larvae 2/ (by Phytodietus, larvaevorids)	Pupae (by Itoplectis, Phaeogenes)	Aggregrate Parasitism
North Powder R.	-	5	24	10	3	37.0
Waterman Flat	Trace	Trace	19	5	1.5	24.3
Chesnimnus	3	1	26	7	7	38.6

2/ Figures are from dissection rather than rearing; no correction is made for estimated success of attack by Omotoma still in egg stage.

TABLE 3. COMPARISON OF PARASITISM OF MATURE BUDWORM LARVAE AS OBTAINED BY REARING AND DISSECTION AT THREE UNSPRAYED STUDY AREAS IN EASTERN OREGON, 1951

Study Method	Corrected No. Specimens 1/	Percent Parasitism by: Omotoma	Ceromasia	Phytodietus	Madreymia	*Lypha*	Unknown Hymenop.	All Parasites
		NORTH POWDER RIVER AREA						
Rearing	102	6.8	2.0	1.0	0	0	0	9.8
Dissection	250	4.4	2.0	3.6	0	0.4	0	10.4
		WATERMAN FLAT AREA						
Rearing	254	0	1.2	0.8	0.8	0	0.8	3.5
Dissection	250	0	0.4	2.8	2.0	0	0	5.2
		CHESNIMNUS AREA						
Rearing	205	0	0	0.5	0	0	0	0.5
Dissection	250	6.0	0	1.2	0	0	0	7.2

1/ All mature larvae still containing the early larval parasite *Glypta fumiferanae* (Vier.) were dropped from the count.

TABLE 4. POPULATION COUNTS OF THE SPRUCE BUDWORM IN EIGHT SPRAYED AREAS IN OREGON AND WASHINGTON IN 1951

Area	Study Line	Year Sprayed	No. Larvae in Buds on 300 15" Twigs	No. Mature Larvae - From 60 minutes beating time per station at 10 stations Total No.	Corrected No. 2/
Roseburg	Henry Mill	1950	18	14	14
	S.& S. Mill	1950	5	2	2
	Clover Creek	1950	1 1/	4	3
Eugene	Creswell	1949	1	16	16
	Sodaville	1949	1	2	2
	Seavey Ranch	1949	1	9	9
	Kampfer Ranch	1949	1	3	3
	Oakridge	1949	3	4	4
McKenzie	Frissel Crossing	1950	7	46	39
Mt. Hood	Wamic	1949	1	6	6
	Bear Springs	1949	74	528	483 3/
	Beaver Butte Cr.	1949	385	2352	2250 3/
S.Umatilla	Nigger Nob	1950	8	18	7
	Madison Butte Rd.	1950	18	71	31
	Red Hill L.O.	1950	18	29	22
Catherine Creek	Bald Mt. Road	1950	45	272	178
	Little Catherine	1950	16	58	44
	Reeves Mt.	1950	76	140	117
Walla Walla	Baby Springs	1950	37	70	43
Tollgate	Langdon Lake	1950	15	51	35

1/ This line consisted of five stations; only 150 15" twigs were taken.

2/ All budworms with parasites that attack overwintering larvae were dropped from the count.

3/ These figures were calculated from a sample of the total larvae collected.

TABLE 5. COMPARISON OF BUDWORM POPULATIONS BEFORE AND AFTER SPRAYING WITH THE POPULATION IN 1951 ON 8 AREAS IN OREGON AND WASHINGTON 1/

		POPULATION IN YEAR OF TREATMENT				POPULATION IN 1951		
AREA AND STUDY LINE	YEAR SPRAYED	No.15" Twigs Sampled	Before Spraying	After Spraying	Per 15" Twig After Spraying	No.15" Twigs Sampled	No. Larvae Found	Per 15" Twig in 1951
Roseburg								
Henry Mill	1950	40	206	2	.050	300	18	.060
S&S Mill	1950	40	336	5	.125	300	5	.016
Clover Creek	1950	40	461	11	.275	150	1	.007
Eugene								
Creswell	1949	30	561	0	.000	300	1	.003
Sodaville	1949	30	362	4	.133	300	1	.003
Seavey Ranch	1949	30	646	18	.600	300	1	.003
Kampfer Ranch	1949	30	358	18	.600	300	1	.003
Oakridge	1949	30	94	0	.000	300	3	.010
McKenzie								
Frissel Cross.	1950	40	192	2	.050	300	7	.023
Mt. Hood								
Wamic	1949	30	238	4	.133	300	1	.003
Bear Springs	1949	36	316	13	.361 2/	300	74	.247
Beaver Butte Cr.	1949	30	438	3	.100 2/	150	385	2.567
S. Umatilla								
Nigger Nob	1950	40	280	2	.050	300	8	.027
Madison Butte	1950	40	326	0	.000	300	18	.060
Red Hill L.O.	1950	40	199	0	.000	300	18	.060
Catherine Cr.								
Bald Mt. Rd	1950	40	572	0	.000	300	45	.150
Little Catherine	1950	40	211	0	.000	300	16	.055
Reeves Mt.	1950	40	259	3	.075	300	76	.253
Walla Walla								
Baby Springs	1950	40	201	3	.075	300	37	.123
Tollgate								
Langdon Lake	1950	40	274	4	.100	300	15	.050

1/ The population counts in 1951 were made of larvae mining the buds (predominantly 4th instar) while the counts for evaluation of control were made in the year of treatment when the larvae were predominantly 5th instar (before spraying), and 6th instar or pupae (after spraying).

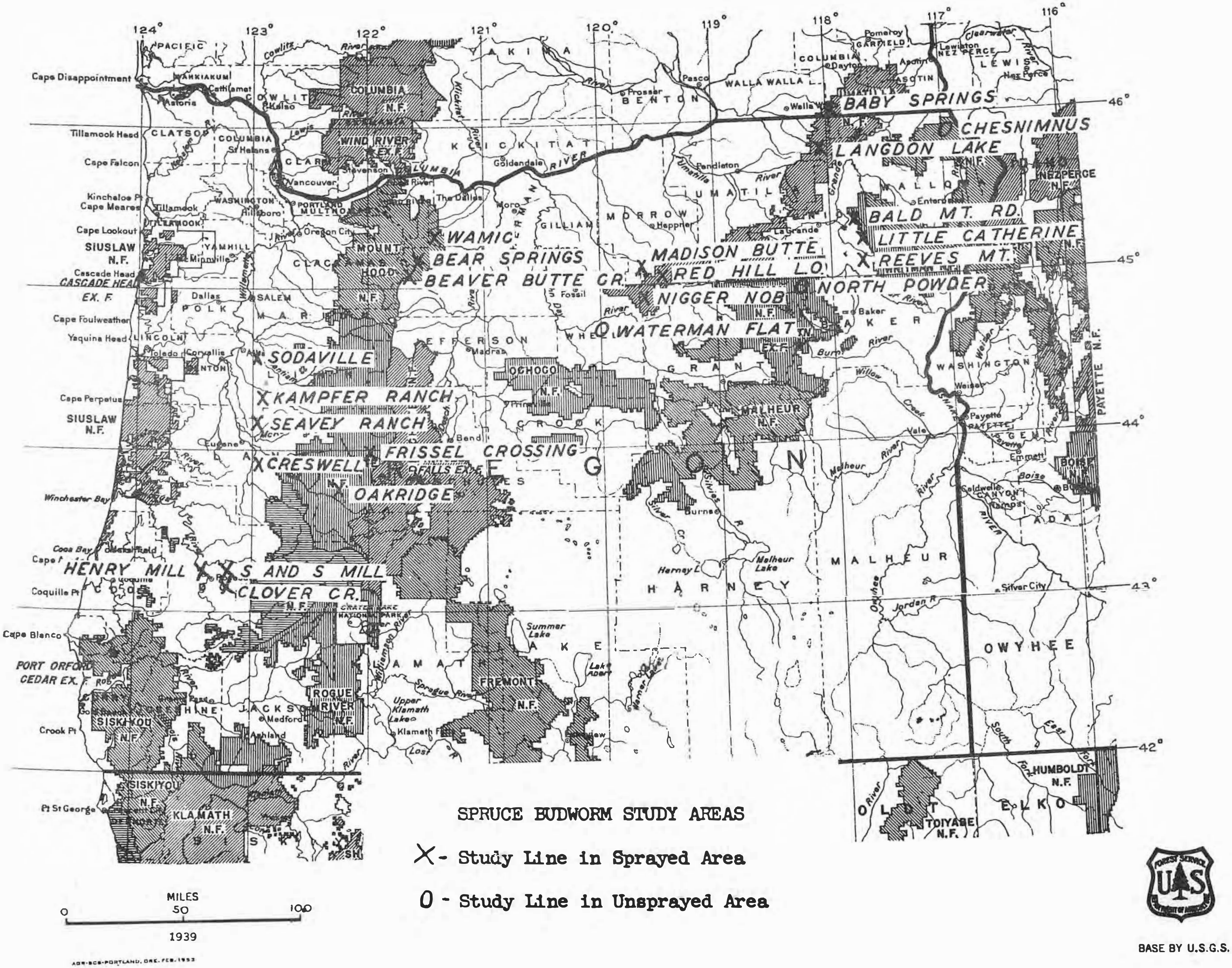
2/ Considerable pupation had occurred adjacent to these areas before spray was applied and is believe responsible for the present population buildup.

TABLE 6. SUMMARY OF PARASITISM OF SPRUCE BUDWORM LARVAE COLLECTED IN SPRAYED AREAS IN OREGON AND WASHINGTON, 1951

	Parasites of Immature Larvae				Parasites of Mature (6th Instar) Larvae								
Area and Locality	No. Larvae	Apanteles	Glypta	Campo-plex	No. Larvae	Actia	Lypha	Phyto-dietus	Omo-toma	Madre-myia	Agria	Meteorus	Other
Roseburg													
Henry Mill	18	4	0	1	14	0	0	5	0	0	0	0	0
S&S. Mill	5	4	0	0	2	0	0	0	0	0	0	0	0
Clover Creek	1	0	0	0	3	0	0	0	0	0	0	0	0
Eugene													
Creswell	2 1/	1	0	0	15	0	3	0	0	0	0	0	0
Sodaville	1	0	0	0	2	0	0	0	0	0	0	0	0
Seavey Ranch	1	1	0	0	9	0	0	0	0	0	0	0	0
Kampfer Ranch	1	0	0	0	3	0	0	0	0	0	0	0	0
Oakridge	3	0	0	0	4	0	0	0	0	0	0	0	0
McKenzie													
Frissel Crossing	7	1	1	0	39	0	12	1	0	0	0	0	0
Mt. Hood													
Wamic	1	0	0	0	6	0	0	1	0	0	0	0	0
Bear Springs	74	12	6	10	110	0	24	8	0	0	0	0	0
Beaver Butte Cr.	100 2/	19	10	1	1103	2	92	5	9	17	0	0	10
S. Umatilla													
Nigger Nob	8	2	0	0	7	0	0	0	0	0	0	0	0
Madison Butte Rd.	18	5	1	7	31	1	0	2	0	0	0	0	0
Red Hill L.O.	18	7	1	3	22	1	0	0	0	0	0	0	0
Catherine Creek													
Bald Mt. Road	45	5	5	10	178	1	0	0	1	0	0	0	0
Little Catherine	16	8	0	0	44	0	0	1	1	0	0	0	0
Reeves Mt.	76	9	3	16	117	5	0	0	7	0	0	2	0
Walla Walla													
Baby Springs	37	15	2	2	43	5	0	0	0	0	0	0	0
Tollgate													
Langdon Lake	15	5	3	2	35	15	0	0	0	1	1	0	0

1/ One of these larvae was obtained from foliage collected in addition to the regular sample.

2/ Total number of larvae collected was 385; 100 were dissected.


BABY SPRINGS
CHESNIMNUS
LANGDON LAKE
BALD MT. RD.
LITTLE CATHERINE
REEVES MT.
MADISON BUTTE
RED HILL L.O.
NORTH POWDER
NIGGER NOB
WATERMAN FLAT
WAMIC
BEAR SPRINGS
BEAVER BUTTE CR.
SODAVILLE
KAMPFER RANCH
SEAVEY RANCH
FRISSEL CROSSING
CRESWELL
OAKRIDGE
HENRY MILL
S AND S MILL
CLOVER CR.
SPRUCE BUDWORM STUDY AREAS
X - Study Line in Sprayed Area
O - Study Line in Unsprayed Area
MILES
0 50 100
1939
BASE BY U.S.G.S.